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Performance Analysis of Fractional Earthworm Optimization Algorithm for Optimal Routing in Wireless Sensor Networks

Venkat Rao Pasupuleti[1,*], Ch. Balaswamy[2]

[1]Department of Electronics and Communication Engineering, Lakireddy Bali Reddy College of Engineering, India.
[2]Department of ECE, Gudlavalleru Engineering College, Gudlavalleru, India.

Abstract

In Wireless Sensor Networks (WSNs), the data transmission from the sensing node to the sink node consumes a lot of energy as the number of communications increases, so the battery life of nodes is limited, and the network also has a limited lifetime. Recent studies show that the bio-inspired meta-heuristic algorithms for solving engineering problems such as energy reduction in autonomous networks in the multidisciplinary areas of WSN, Internet of Things (IoT) and Machine learning models. Hence to increase Network lifetime, optimized clustering and energy-efficient routing techniques are required. In all applications of WSN, not only energy-efficient but also delay and throughput of the network are important for efficient transmission of data to the destination. This paper analyses optimized clustering by selecting cluster heads based on fractional calculus earthworm optimization algorithm (FEWA). The route from cluster heads to sink node is selected based on the fit factor. This paper's main intention is to provide an extensive comparative study of the FEWA with all standard optimization-based clustering and routing techniques. This method's performance is compared with existing optimized clustering methods like GA, PSO, ACO, DE and EWO in terms of the number of energy, delay, and throughput. At the end of 1000 iterations, the analysis shows that the FEWA outperforms existing methods with maximum average remaining energy of the nodes as 0.216J, the minimum average delay of 0.208 sec and maximum average throughput of 88.57% for 100 nodes.

Keywords: clustering, routing, optimization, earthworm optimization algorithm, fractional calculus.

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*Corresponding author. E-mail address: venkat2k15@gmail.com

1. Introduction

WSN finds various applications in gathering environmental data and solving real-world data gathering problems [1]. To boost the battery life of the network, efficient data aggregation procedures are required. Clustering is a data aggregation approach that enables a network's energy efficiency to achieve efficient transmission, load balance, and scalability. Many clustering algorithms exist in the literature, and very few concentrates on optimizing the necessary WSN constraints. Optimization algorithms are iterative-based approaches used to achieve the desired solution problem outcome. It gives an optimum solution because it is minimized or maximized using one of the many optimization routines. Fractional calculus in engineering applications has been one of the most useful tools recently. It is an analysis of differential problems as fractional derivatives from mathematical calculus. The function of fractional calculation in different fields, such as mechanics, electricity, chemistry, biology, economy, notably control theory, and signal and image processing, has been very significant in recent years [2]. New trending approaches used to optimize engineering problems are bio-inspired methods of optimization. Clustering approaches on wireless sensor networks focused on optimization have brought promising advances over conventional clustering algorithms. This paper uses a newly developed bio-inspired optimization method for cluster head selection, called the FEWA algorithm [3].

sensor node after completing all the rounds, delay, number of alive nodes at the end of last round and throughput of the network. These performance parameters are calculated by using the following expressions.

$$\text{Energy} = \begin{cases} \mathrm{E_i} - [(E_{tx} + E_{da}) \times 10^3 + E_{amp} \times 10^3 \times (d^4)]; \text{ if } \mathrm{d} > \mathrm{d_0} \\ \mathrm{E_i} - [(E_{tx} + E_{da}) \times 10^3 + E_{amp} \times 10^3 \times (d^2)]; \text{ if } \mathrm{d} \leq \mathrm{d_0} \end{cases}$$

$$\text{where } \mathrm{d_0} = \sqrt{\frac{\mathrm{E_{fs}}}{\mathrm{E_{amp}}}}$$

$$\text{Number of alive nodes} = \#\text{nodes with Energy} > 0 \text{ for the current round}$$

$$\text{Overall Delay} = \frac{\text{time at which the packet is sent from node}}{\text{time it is revieved by sink node}}$$

$$\%\text{ of Throughput} = \frac{\text{Number of packets recieved at base staion node}}{\text{Number of packets sent to base station node}} \times 100$$

All these performance parameters are compared for the proposed FEWO algorithm with other existing cluster-based optimization methods GA [18], PSO [19], DE [20], ACO [21], and EWO [22]. This method is simulated for different similarity factor values and different population sizes, and in comparative analysis, we choose $\alpha = 0.64$ and population size=30.

4.2. Comparative Discussion

4.2.1 Comparison in terms of number of alive nodes

Figure 5 provides a comparison of the number of live nodes for the strategy with the number of rounds dependent on PSO, EWA-based clustering and GA-based clustering. At the end of the 700 round, 91 for FEWA and 81 for PSO, 52 for EWA, and 86 for GA are provided for nodes still alive with some residual energy. The following figure shows clearly, as the number of dead nodes is smaller than other approaches, the algorithm will improve the network's existence.

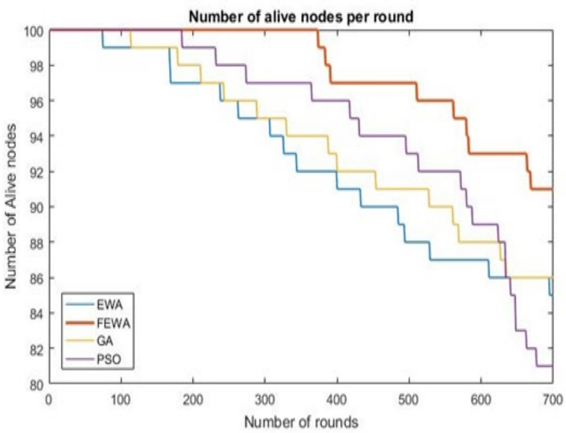

Figure 5. Comparative analysis of the number of nodes alive

4.2.2 Comparison in terms of delay

Figure 6 compares the delay value for the technique with the number of rounds with optimized clustering algorithms. At the end of the 1000 rounds, the delay evaluated by GA, PSO, DE, ACO, EWO, and proposed FEWA are 0.639sec, 0.583sec, 0.832sec, 0.604sec, 0.433sec, and 0.240sec. The contrast curve below shows that the algorithm can do better with less delay than others so that more transmissions can be done in a given time.

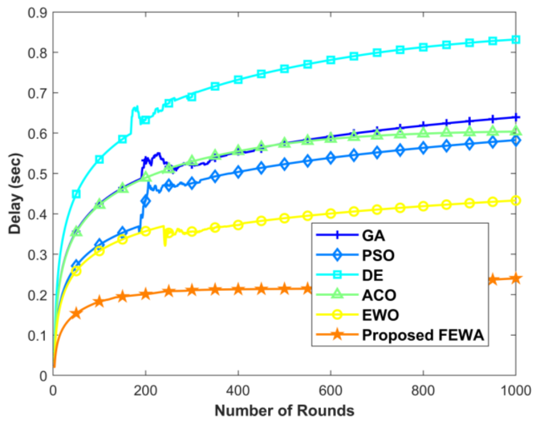

Figure 6. Comparative analysis of based on the overall delay

4.2.3 Comparison in terms of throughput

Figure 7 compares the throughput percentage value for the optimization-based clustering process to the number of rounds. At the conclusion of the 1000 rounds, the % of throughput values evaluated by GA, PSO, DE, ACO, EWO, and proposed FEWA are 0%, 0%, 0%, 0%, 0%, and 10% respectively. From the graph, it is clear that the throughput is improved for the proposed method.

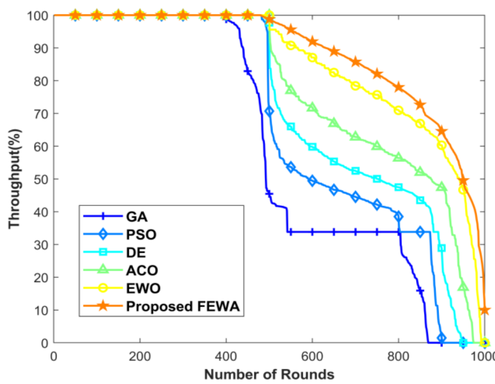

Figure 7. Comparative analysis based on throughput

4.2.4 Comparison in terms of energy

Figure 8 demonstrates the methodology's energy value relationships with other comparative methods in several rounds. At the end of the 1000 rounds, the energy evaluated by GA, PSO, DE, ACO, EWO, and proposed FEWA are 0J, 0J, 0J, 0J, 0J, and 0.019J. From the curve below, while the system's energy is smaller initially, but as the number of rounds increases, the residual energy at the end of the 1000 round is high relative to the other methods.

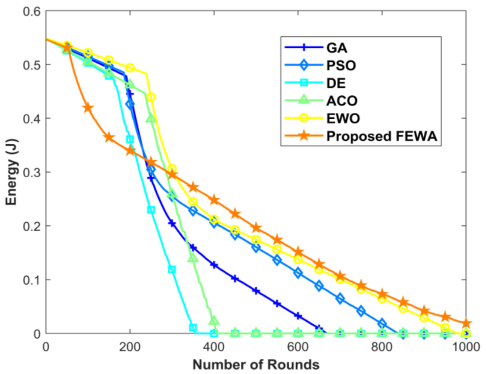

Figure 8. Comparative analysis of based on the overall delay

4.2.5 Comparative discussion in terms of average values:

The proposed FEWO method's performance is compared with other existing standard optimization algorithms after implementing them in our WSN scenario. The average values of performance parameters like delay, energy and throughput are mentioned in table 3 and table 4 with several nodes that are 50 and 100.

Table 3. Comparison of FEWO algorithm with other optimization methods in terms of average values for 50 nodes

Parameters	Number of nodes = 50					
	GA	PSO	DE	ACO	EWO	FEWO
Delay (sec)	0.276512	0.40213	0.48252	0.32681	0.22015	0.082910
Energy (J)	0.179173	0.146672	0.13750	0.184522	0.220343	0.330175
Throughput (%)	64.86866	68.35754	72.41174	77.81489	85.79964	87.80326

Table 4. Comparison of FEWO algorithm with other optimization methods in terms of average values for 100 nodes

Parameters	Number of nodes = 100					
	GA	PSO	DE	ACO	EWO	FEWO
Delay (sec)	0.547308	0.486158	0.715442	0.537612	0.374691	0.208665
Energy (J)	0.165354	0.202258	0.124864	0.153053	0.232226	0.216422
Throughput (%)	60.0141	67.10725	71.97621	77.66661	85.35704	88.57683

5. Conclusion

This paper presents the comparative analysis of the FEWA optimization method to integrate earthworm optimization algorithms with fractional calculus. The fractional derivative is used for calculating the position of the final earthworm after the two reproduction systems. By selecting the proportional constant 0.64 and the population size 30, the proposed Fractional Earth Worm Optimization algorithm (FEWA) is implemented in the WSN environment with 100 nodes and 100×100 square meter area with a sink node centre. The simulated results prove that the proposed algorithm gives better minimization for standard optimization functions. Further, the performance parameters like the number of alive nodes, residual energy, delay and throughput for the FEWO algorithm is compared with earlier reported optimization algorithms in the literature. This analysis shows that the implemented algorithm can perform well compared to the other standard optimization algorithms used in cluster head and routing techniques in wireless sensor networks. This work can be extended by implementing any hybrid optimization algorithm with multi-objective methods to further improve energy efficiency and network lifetime. The future extension of this research is to develop a hybrid optimization algorithm with fractional calculus. It would be interesting to recognize missing sensor data values in real-time environmental data using higher-order tensor completion models.

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